PRE-DEVELOPMENT SURVEY
WATER QUALITY ASSESSMENT
OF
JAY LAKE
AUSTIN LAKE
GRASSY LAKE
DISTRICT OF KENORA

WATER RESOURCES ASSESSMENT
TECHNICAL SUPPORT SECTION
NORTHWESTERN REGION
APRIL, 1976

Ministry of the Environment
Ontario

L. F. Pitura
Director
Northwestern Region

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BY

R. B. VAREY
WATER ASSESSMENT
TECHNICAL SUPPORT SECTION
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INTRODUCTION

During the summer of 1975 a general water quality assessment of Jay, Austin and Grassy Lakes was undertaken in relation to a proposed subdivision which borders on all three lakes. Neither the surrounding area nor the lakes have experienced prior cultural influence. This situation provides a unique opportunity for a "before" and "after" study to evaluate the effect of cottage development, and it is essential for meaningful management of Canadian Shield resources that a better understanding of such developments be gained.

The following report documents background data and establishes the trophic status of each lake.

DESCRIPTION OF STUDY AREA

The study area is approximately 15 miles north of Kenora in the Northern part of Melick Township, near the boundary of Reddit Township.

Land:

The physical nature of the subdivision site is characterized by exposed Precambrian bedrock overlain in some areas by thin glacial drift composed largely of sand and gravel. Jackpine, (*Pinus banksiana*), black spruce, (*Picea mariana*) and trembling aspen (*Populus tremuloides*) constitute the predominant forest species.

Lakes:

Jay, Austin and Grassy Lakes (Table I) are three small bodies of water bordering on "brown-water" classification.

There is a limited inflow to the system via Grassy Lake and no apparent out-flow, (Diagram 1).

TABLE 1. AREA (A_O) MEAN DEPTH ($\bar{z}$) AND VOLUME (V)

LAKE	A_O (m^2)	$\bar{z}$ (m)	V (m^3)
JAY	75,025	3.6	270,090
AUSTIN	525,176	6.0	3,151,056
GRASSY	700,235	3.8	2,660,893

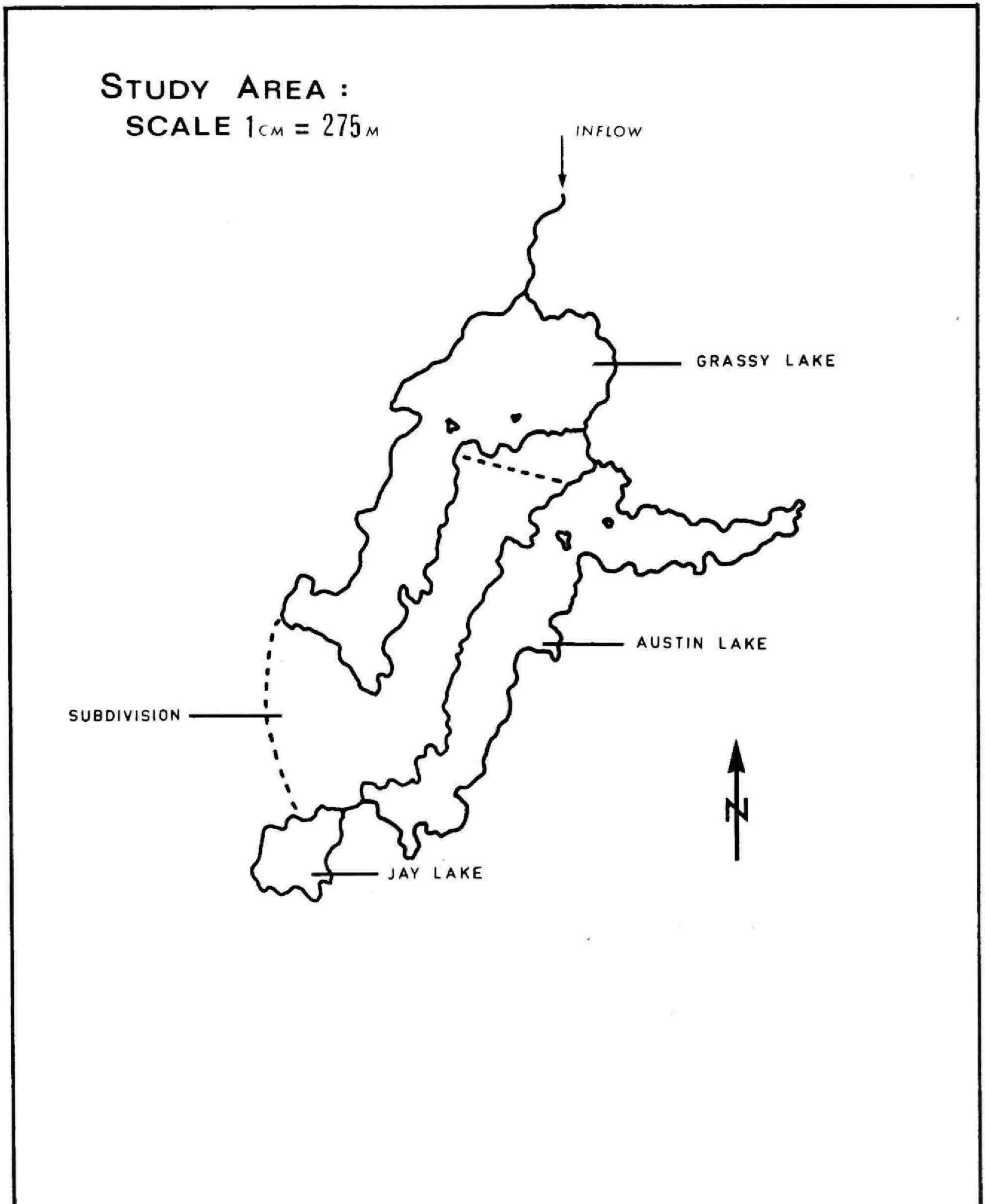
METHODS

A two-week sampling cycle was used. Austin and Grassy Lakes were sampled four times, and Jay Lake was sampled three times.

Chlorophyll *a* samples were collected in 1 litre glass bottles as composite samples from the euphotic zone. The depth of the euphotic zone was theoretically determined as twice the Secchi disc depth to yield approximately the level of 1% incident light. 300-1000 mls. of the sample were filtered through 1.2u 'Millipore' filter paper under a vacuum of approximately 1.0 kg/sq. cm. The filtered samples were placed in plastic containers covered in aluminum foil and stored at -15^o to -20^{o}C. Chlorophyll *a* concentrations were later determined at the laboratory, by 90% acetone extraction and UV- visible spectrophotometry.

Oxygen and temperature regimes were determined directly in the field with a YSI model 54 oxygen-temperature meter.

Diagram 1


STUDY AREA :
SCALE 1CM = 275M
INFLOW
GRASSY LAKE
AUSTIN LAKE
SUBDIVISION
JAY LAKE
N

Samples for determination of chemical parameters were collected from the epilimnion, (1 metre below the lake surface) metalimnion (where applicable) and hypolimnion (1 metre above the lake bottom). These samples were taken with a 6 litre Van Dorn water sampler, placed in 1 litre glass bottles and transported to the Laboratory for analysis. The analyses were carried out as per Standard Methods for the Examination of Water and Waste Water, Twelfth Edition, American Public Health Association, New York, 1971.

Lake area (A_0) was determined using a planimeter and soundings were taken to determine mean depth ($\bar{z}$). Volume was calculated as a product of (A_0) and ($\bar{z}$).

RESULTS AND DISCUSSION:

(a) Transparency - Chlorophyll *a* relationship:

The transparency of lake water to incident light is measured by lowering a Secchi disc, 20 cms in diameter with alternate black and white quadrants, into the water on the shaded side of the boat. The depth at which the disc disappears is noted as well as the depth at which it reappears. The mean of the two readings is termed the Secchi disc depth. Vollenweider (1969) found that twice the Secchi disc depth approximates the level of 1% incident light and this level has been found sufficient to support active photosynthesis by algae, but is used as the approximate limit of the euphotic zone.

The measure of chlorophyll *a* (Table 2) in samples from the euphotic zone represent the amount of photosynthetic pigment present. This in turn, reflects the standing crop of phytoplankton as a result of primary productivity at any

one time. The mean of samples taken over the summer months is a reasonable measure of average productivity. Mean levels of 7.3 μg/l for Austin Lake and 6.1 μg/l for Grassy Lake constitute conditions which normally do not impede recreational activity. Levels as high as that obtained in Jay Lake (24.8 μg/l) constitute deterioration of the lakes' potential for recreational activities and aesthetic qualities.

TABLE 2: TRANSPARENCY-CHLOROPHYLL *a* RELATIONSHIP

	JAY		AUSTIN		GRASSY	
	SECCHI DISC (m) DEPTH	CHLORO *a* (μg/l)	SECCHI DISC(m) DEPTH	CHLORO *a* (μg/l)	SECCHI DISC(m) DEPTH	CHLORO *a* (μg/l)
8/7/75			2.0	10.3	1.9	4.1
22/7/75			2.5	6.1	1.6	6.1
30/7/75	2.9	41.8				
5/8/75	2.8	19.8	2.4	8.7	1.9	6.6
19/8/75	2.6	12.7	1.8	4.0	1.2	7.7
MEAN	2,8	24.8	2.2	7.3	1.7	6.1

The low Secchi disc readings for the study lakes (1.2 -2.9m) are consistent with the relatively high chlorophyll a levels. This relationship is common in lakes with high primary productivity.

(b) Conductivity and Total Dissolved Solids:

Total ionic activity, measured as conductivity is utilized in determining total dissolved solids (T.D.S.). A simple conversion factor of .65 is used to obtain T.D.S. values (Table No.3), i.e. Conductivity x .65 = T.D.S.

TABLE 3: CONDUCTIVITY-TOTAL DISSOLVED SOLIDS

DATE	JAY		AUSTIN		GRASSY	
	COND. (umho/cm)	T.D.S. (mg/l)	COND. (umho/cm)	T.D.S. (mg/l)	COND. (umho/cm)	T.D.S. (mg/l)
8/7/75			41.7	27.1	37.0	24.1
22/7/75			38.0	24.7	37.5	24.4
30/7/75	53.5	34.8				
5/8/75	44.0	28.6	48.5	31.5	39.5	25.7
19/8/75	40.0	26.0	41.0	26.7	37.5	24.4
MEAN	45.8	29.8	42.3	27.5	37.9	24.7

Lakes in this area of the Canadian Shield are low in dissolved solids (low conductivity) in comparison to bodies of water whose watersheds drain a more soluble geological substrate, (e.g. Lake of the Woods, cond. = 100 umho/cm)

(c) Morpho-edaphic Index:

R. A. Ryder (1965), in describing a method for estimating potential fish production of north temperate lakes, stated that yield is affected by (a) morphometric, (b) edaphic (those factors related to soils) and (c) climatic factors. In applying a system whereby biological productivity can be estimated, only morphometric and edaphic conditions need be considered if the climate in the study area is relatively homogeneous. Hence, the productivity of a group of lakes in a discrete area can be predicted by a measure of the ratio of total dissolved solids in mg/l to mean depth in feet (VanderWal and Stedwill, 1975).

Total dissolved solids, reflect, in some relationship, concentration of ions in lake waters; usually giving an approximate indication of fertility. Concentrations of limiting nutrients in a body of water are a relevant index of potential productivity only where phytoplankton and macrophyte stocks can utilize this reserve, i.e. in the euphotic zone. Mean depth then becomes an important variable since as lake depth decreases, a greater proportion of the lake volume and the water-sediment interface are contained in the zone of photosynthetic activity and hence, the efficiency of primary production is increased. The likelihood of stable density stratification is higher in moderately deep lakes as compared with relatively shallow lakes. It has been suggested that cold hypolimnial waters act as a nutrient sink and make these nutrients unavailable to primary producers during long periods of time (Rawson, 1952). Furthermore, it has been shown that shallow waters

develop higher temperatures than do deeper lakes, resulting in increased biological activity.

Although the M.E.I. strictly speaking has been formulated to give approximations of fish yield, it is felt that the index must, for the same reasons that it reflects productivity at higher trophic levels, be applicable to productivity at a primary level. Since the definition of high water quality in this study is inversely correlated with biological productivity, the high M.E.I. values for the study lakes are indicative of low water quality (Table 4).

TABLE 4 MORPHOEDAPHIC INDEX

LAKE	T.D.S./$\bar{Z}$	M. E. I.
Jay	29.8/3.6	8.3
Austin	27.5/6.0	4.6
Grassy	24.7/3.8	6.5

The range in M.E.I. (4.6-8.3) falls between values for highly enriched Lake Erie (11.1) and Lake of the Woods (3.7).

(d) Total Phosphorus

The concentration of total exchangeable phosphorus (P) in natural waters is determined primarily by (1) basin morphometry as it relates to volume and dilution, and to stratification or water movements, (2) chemical composition of the geological formations of the area as they contribute dissolved phosphate (3) drainage area features in relation to introduction of organic matter; and (4) organic metabolism within the body of water, and the rate at which phosphorus is lost to the sediments (Reid, 1961).

It has been indicated (Michalski and Conroy, 1973) that troublesome levels of algae can be expected to materialize when mean total phosphorus concentrations during ice free season exceed .020 mg/l. With the exception of the surface water in Jay Lake (.019 mg/l), phosphorus concentrations at all stations (Table 5) are in excess of the above criterion.

TABLE 5: TOTAL PHOSPHORUS (P)
(mg/l)

1 METRE BELOW LAKE SURFACE AND 1 METRE ABOVE LAKE BOTTOM

DATE	JAY		AUSTIN		GRASSY	
	SURF.	BOTTOM	SURF.	BOTTOM	SURF.	BOTTOM
8/7/75			.055	.071	.036	.040
22/7/75			.022	.037	.039	.046
30/7/75	.024	.130				
5/8/75	.014	.062	.022	.081	.042	.044
19/8/75	.018	.088	.020	.066	.030	.028
MEAN	.019	.093	.030	.064	.037	.040

Brydges, 1971, has shown that under anaerobic conditions, nutrients, particularly phosphorus, may be released from sediments into the bottom waters. The ratio of total iron to total phosphorus in the bottom waters provides an indication of the extent of this recycling process. Low ratios indicate a significant degree of recycling, while high ratios indicate that significant recycling is not occuring. A summary of iron to phosphorus ratios at sites in the study area, exhibiting anaerobic or near anaerobic conditions in their bottom waters, is presented in Table 6.

TABLE 6: IRON-PHOSPHORUS RATIO

DATE	JAY		AUSTIN	
	Fe (mg/l)	P (mg/l)	Fe (mg/l)	P (mg/l)
8/7/75			3.6	.071
19/8/75	.94	.088	2.1	.066
MEAN	.94	.088	2.7	.069
RATIO	10.7		39.1	

(e) Nitrogen and Nitrogen Compounds:

The importance of nitrogen in aquatic ecosystems rests upon its role in the synthesis and maintenance of protein.

Little organic nitrogen is available as nutrient for plants and animals. As a consequence, measurements of inorganic nitrogen compounds (ammonia, nitrate, nitrite) are felt to be a better measure of productivity (Reid, 1961). In most fresh waters the concentrations of these inorganic compounds are relatively slight, as is the case in the study lakes. Ammonia and nitrite ranges fall below detection limits and the nitrate range is just above the detectable limit (Table 7). The high total Kjeldahl nitrogen (T.K.N.) indicates that much of the nitrogen is tied up in organic material.

TABLE 7: RANGE OF CONCENTRATIONS FOR NITROGEN COMPOUNDS (mg/l)

Compound	Jay Lake	Austin Lake	Grassy Lake
T.K.N.	.52-1.4	.50-1.3	.59-.88
$N.H._3$	.01- .02	.01- .04	.01-.09
NO_2	.003-.025	.003-.025	.003-.006
NO_3	.01- .07	.01- .01	.01-.03

(f) Dissolved Oxygen Distribution:

The type of oxygen distribution found in a lake is the product of (a) production of oxygen by photosynthetic organisms in the presence of sunlight, (b) depletion of oxygen by respiring organisms (c) the stability of thermal density stratification and (d) absorption of oxygen from the atmosphere.

Bottom water oxygen deficits and corresponding clinograde oxygen distributions in the study lakes (Figure 1) indicate substantial synthesis of nutrients into plant material and its subsequent decomposition at the expense of the oxygen resources in the hypolimnion. This reflects an extreme vulnerability of these lakes to artifical inputs of domestic wastes (Brydges, 1971).

(g) Carbon Dioxide:

Carbon Dioxide (CO_2) is extremely important as a contributor to the "fitness" of natural waters. It serves in a more or less purely chemical sense to "buffer" the environment against rapid shifts in acidity-alkalinity states. The fact that the compound contains carbon, and as a result is responsible for the availability of this element for chemical combination, is paramount to the balancing of aquatic ecosystems.

High CO_2 levels such as those in the hypolimnia of the study lakes (Table 8) are indicative of high acidity. This means that there is a greater probability for significant shifts in pH.

Figure 1

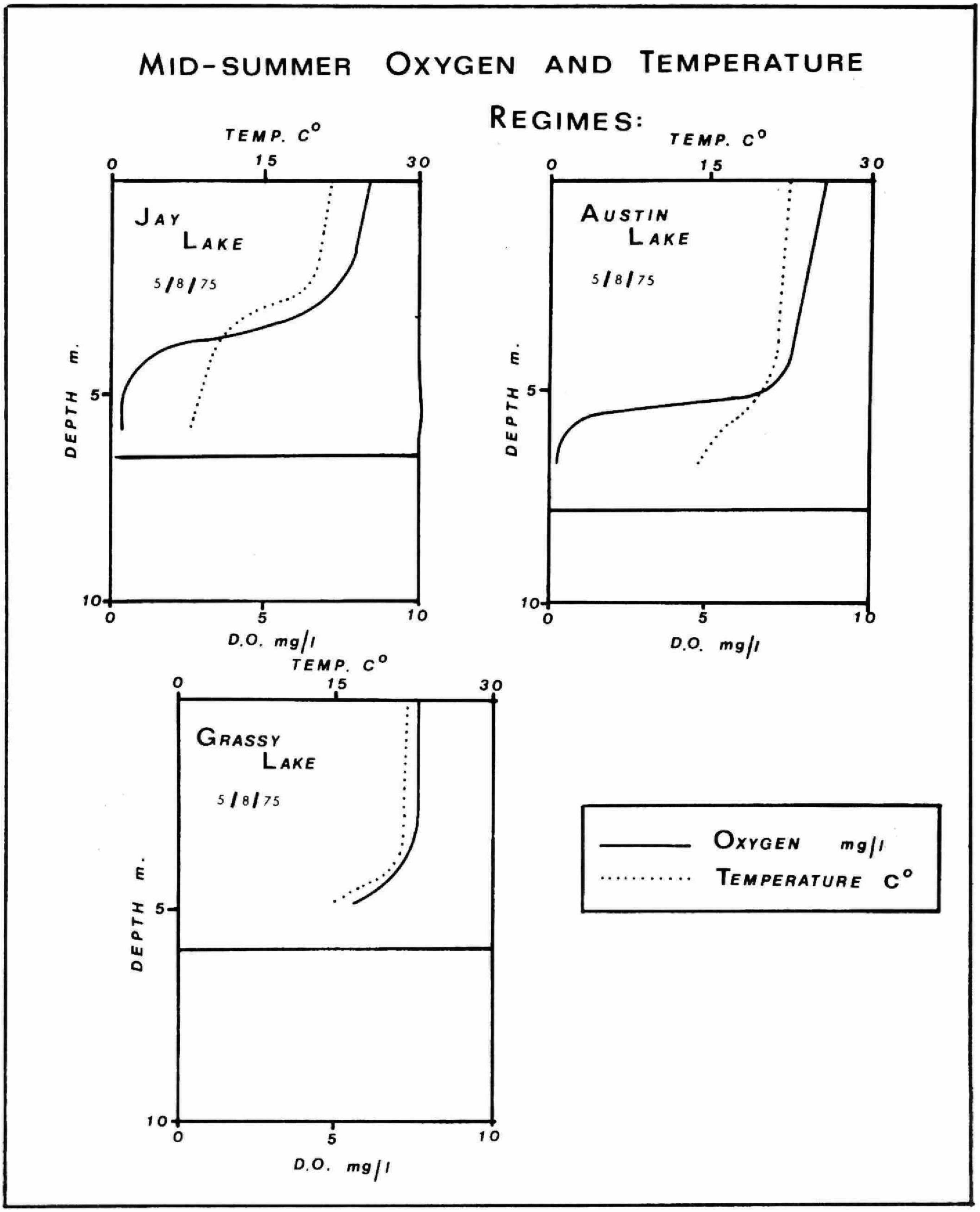

MID-SUMMER OXYGEN AND TEMPERATURE REGIMES:
TEMP. C°
0
15
30
JAY LAKE
5/8/75
DEPTH m.
5
10
0
5
10
D.O. mg/l
TEMP. C°
0
15
30
AUSTIN LAKE
5/8/75
DEPTH m.
5
10
0
5
10
D.O. mg/l
TEMP. C°
0
15
30
GRASSY LAKE
5/8/75
DEPTH m.
5
10
0
5
10
D.O. mg/l
OXYGEN mg/l
TEMPERATURE C°

TABLE 8: CARBON DIOXIDE (CO_2) CONCENTRATIONS (mg/l) 1 METRE BELOW LAKE SURFACE AND 1 METRE ABOVE LAKE BOTTOM

DATE	JAY		AUSTIN		GRASSY	
	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM
8/7/75			1.6	12.3	2.6	4.4
22/7/75			1.8	2.6	2.2	2.7
30/7	2.6	18.4				
5/8/75	2.6	15.1	2.8	12.4	3.2	3.6
19/8/75	6.1	17.1	2.8	12.9	2.6	4.0

(h) Calcium and Magnesium:

Together, these two elements constitute the most abundant ions in fresh waters. The chemical activity of each is similar, particularly in the formation of carbonate salts and both may limit biological processes.

Calcium is generally present in all natural waters at levels which depend on the amount of contact with specific geological formations. The extremely low calcium concentrations in the study lakes can be explained by the absence of these deposits (limestone, dolomite, gypsum and gypsiferous shale).

Magnesium is present in all natural waters and is generally associated with the presence of calcium. In waters containing less than 50 mg/l T.D.S. they are, on the average, in a ratio of 1:5 respectively (Reid, 1961).

Both elements are major contributors to water "hardness". The low values for each study lake (Table 9) reflect the "soft" nature of shield lakes in general.

In the absence of normal calcium concentrations, carbonic acid produced during biological activity becomes more apparent and low values for alkalinity are obtained (this results from free acid remaining free rather than combining with Ca to form $CaCO_3$).

Both sets of values (Table 9) are calculated from total hardness, i.e.:

$$Ca = Hardness/2.5 \times .8$$

$$Mg = Hardness - (Ca \times 2.5)$$

TABLE 9: CALCIUM AND MAGNESIUM CONCENTRATIONS (Mg/1)

DATE	JAY			AUSTIN			GRASSY		
	Hard	Ca	Mg	Hard	Ca	Mg	Hard	Ca	Mg
8/7/75				18	6	1	17	5	1
22/7/75				15	5	1	16	5	1
30/7/75	21	6	2						
5/8/75	17	6	1	18	5	1	15	5	1
19/8/75	15	5	1	16	5	1	15	5	1
MEAN	18	6	1	17	5	1	16	5	1

(i) Acidity:

The acidity of water is a measure of its capacity to neutralize a base. The major acidic component of natural waters is carbonic acid which is formed by the atmospheric absorption of carbon dioxide or by the release of carbon dioxide as a metabolic by-product.

Results for acidity are reported as mg/l of $CaCO_3$. This represents the quantity of base, expressed as calcium carbonate needed to increase the pH of a measured portion of a sample to 8.3.

The high acidity values obtained for the hypolimnion of Jay and Austin Lakes (Table 10) indicate that their buffering capacity is low.

TABLE 10: Acidity Concentration (mg/l) 1 Metre Below Lake Surface and 1 Metre Above Lake Bottom

DATE	JAY		AUSTIN		GRASSY	
	Surf.	Bottom	Surf.	Bottom	Surf.	Bottom
8/7/75			2	14	3	5
22/7/75			2	3	3	3
30/7/75	3	21				
5/8/75	3	17	3	14	4	4
19/8/75	7	20	3	15	3	5
MEAN	4	19	3	12	3	4

(j) Alkalinity:

The alkalinity of a water is a measure of its capacity to neutralize acid. In neutral waters the main component of the alkalinity is the bicarbonate ion which may be formed by the action of dissolved carbon dioxide on limestone or other calcium type deposits. In the absence of these deposits the bicarbonate ion concentration is correspondingly low and acidity is high.

Alkalinity is reported as mg/l of $CaCO_3$. This does not necessarily imply that there is this much calcium carbonate in the water or that there is any at all. The alkalinity measurement represents the quantity of acid, expressed as calcium carbonate, needed to reduce the pH of a measured portion of sample to 4.5.

The alkalinity of a water is generally used to define the buffering capacity of the water's capability to resist a change in pH. This means that if an acidic waste is discharged to a natural system, the effect on the water may not necessarily be detected as a pH change, but will be detected as a drop in alkalinity.

Low values for alkalinity in the study lakes (Table 11) indicate that the waters' ability to buffer is low. As a result, an acid discharge to any of these lakes would, in all probability, result in a pH change.

TABLE 11: Alkalinity ($CaCO_3$) Concentration (mg/l)

DATE	JAY	AUSTIN	GRASSY
8/7/75		17.6	14.9
22/7/75		13.0	12.5
30/7/75	14.8		
5/8/75	9.8	16.5	13.5
19/8/75	11.4	15.8	13.8
MEAN	12.0	15.7	13.7

(k) pH:

PH is a measure of the hydrogen ion concentration in water; specifically, it is the negative logarithm of the free hydrogen ion concentration. Thus, each change of one unit in pH corresponds to a 10-fold change in the hydrogen ion concentration. As a result, small shifts in pH can be critical to species habitat.

Hypolimnetic decreases in pH, such as those exhibited in the study lakes (Table 12), are the result of carbonic acid formation. This unstable condition indicates an imbalance in the bicarbonate buffering system.

TABLE 12: RANGE OF pH FOR:

DEPTH	JAY RANGE	AUSTIN RANGE	GRASSY RANGE
1 Metre below surface	6.8-7.2	7.1-7.3	6.9-7.1
1 Metre above bottom	6.2-6.4	6.2-6.4	6.6-7.0

(1) Sulphur:

The most frequently encountered forms of sulphur in fresh waters are as the anion sulphate (SO_4). It is ecologically important in natural waters in several ways: 1) necessary for plant growth, 2) required for protein metabolism and 3) instrumental in the liberation of phosphate under anaerobic conditions.

Sulphate usually varies between 1 and 40 mg/l in natural waters. Levels such as those obtained for the study lakes (Table 13) are consistent with other bodies of water in the area (Armstrong and Schindler, 1971).

TABLE 13: SULPHUR (SO_4) CONCENTRATION (mg/l) 1 METRE BELOW LAKE SURFACE AND 1 METRE ABOVE LAKE BOTTOM

Dates	Jay		Austin		Grassy	
	Surf.	Bottom	Surf.	Bottom	Surf.	Bottom
8/7/75			3	3	4	3
22/7/75			3	3	3	3
30/7/75	3	7				
5/8/75	2	4	2	4	4	4

Under anoxic conditions, sulphates serve as an oxygen source for bacteria which convert it to hydrogen sulphide gas; the latter is recognizable by its characteristic odour of rotten eggs.

(m) Colour:

Colour, measured in Hazen Units (H.U.), is primarily associated with the presence of humic acids derived from the decomposition of plant material such as plankton, acquatic macrophytes, terrestrial leaves and logs. Lakes containing these coloured substances are commonly referred to as "brown-water" lakes.

Only the apparent colour is reported since it is considered most representative of field conditions. "Apparent colour" includes the colour due to dissolved substances as well as the additional colour contributed by suspended matter.

The study lakes exhibit a range from 20 H.U. to 70 H.U. (Table 14). These values are far in excess of the specified objective of 5 H.U. for domestic water supplies. However, the fact that the water is considered unacceptable for drinking purposes is based solely on aesthetic considerations and not on known health hazards.

TABLE 14: COLOUR (H.U.) ONE METRE BELOW LAKE SURFACE AND ONE METRE ABOVE LAKE BOTTOM

DATES	JAY		AUSTIN		GRASSY	
	SURF.	BOTTOM	SURF.	BOTTOM	SURF.	BOTTOM
8/7/75			20	70	60	60
22/7/75			20	40	60	60
30/7/75	30	70				
5/8/75	30	70	30	70	60	60
19/8/75	40	70	20	70	70	70

(n) Metals:

Water analysis for the following list of heavy metals indicated that detectible levels were absent.

	METAL	DETECTION LIMIT
1)	Lead	.004
2)	Copper	.001
3)	Nickel	.002
4)	Cobalt	.004
5)	Cadmium	.001
6)	Mercury (mg/l)	.08

The apparent absence of these elements can be attributed to their residence time in natural waters. As soon as they enter the system they are adsorbed to organics and minerals.

Trace levels exist for the majority of heavy metals (unsubstantiated in this study) with a contributed benefit to the environment. However, high concentrations of these elements often create a condition of toxicity.

(o) Microbiology:

Recreational waters are considered impaired when the coliform, faecal coliform and faecal streptococci geometric mean densities exceed 1,000, 100 and 10 per 100 ml. respectively. Values obtained for the study lakes (Table

15) are far below the acceptable limits.

TABLE 15: BACTERIAL GEOMETRIC MEANS (/100 ml.)

LAKE	COLIFORM	FAECAL COLIFORM	FAECAL STREPTOCOCCI
JAY	54.7	0	0
AUSTIN	48.6	0	0
GRASSY	13.0	0	0

Conclusions:

The low or undetectable levels for most of the heavy metals are typical of Shield lakes in the area (Armstrong and Schindler, 1971). The remainder of the measurable parameters are consistent with a total picture of high primary productivity.

The restricted water depth, clinograde oxygen distributions with anaerobic hypolimnia, high phosphorus levels, reduced clarity and very high potentials for biological production, are consistent with classical characteristics of eutrophy.

The consequences of continued eutrophication as a result of cultural development and increased nutrient loading might be severe. More specifically, the presently imbalanced bicarbonate buffering system may become ineffective in resisting a pH change, should increased production result in increased hypolimnial biodegradation with the simultaneous release of acidifying by-products.

RECOMMENDATIONS

(1) Development of cottages and dwellings and disposal of domestic wastes should be regulated using the MOE water quality criteria for recreational use.

(2) Continued monitoring of the study lakes should be conducted by either:

- (a) MOE staff or
- (b) members of the community with the guidance of the Ministry of the Environment

(3) Upon completion of the construction an intensive post-development survey should be conducted. This information coupled with that of the pre-development survey should provide a valuable insight into the problems of development on small shield lakes.

GLOSSARY OF TERMS

Anaerobic	- a condition where the oxygen level is greatly depressed
Anoxic	- a condition where there is a complete lack of oxygen
Clinograde	- a type of vertical oxygen distribution where there is a decrease in oxygen levels with depth
Epilimnion	- the uppermost region of warm, homothermal water in a lake
Euphotic zone	- the lighted region that extends vertically from the waters surface to the level at which photosynthesis fails to occur because of ineffective light penetration
Eutrophic ("rich food")	- a condition in which a lake is considered highly productive
Hypolimnion	- the bottom region of cool, homothermal water in a lake
Macrophyte stocks	- macroscopic aquatic plants
Phytoplankton	- free-floating chlorophyll bearing micro organisms
Primary Productivity	- is the rate at which energy-containing material is formed by plants

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